Development of Fertilizer from Dairy Waste and Its Effect on Soil Properties, Growth and Yield of *Sorghum bicolor* L.

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SYNOPSIS

SUBMITTED IN THE PARTIAL FULFILMENT FOR THE REQUIREMENT OF

DOCTOR OF PHILOSOPHY

IN

BOTANY

Submitted By

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2022

INTRODUCTION

In present time availability of food to the world's more than 7.8 billion people (World Population review, 2021) is becoming a challenge of great priority, which will continue to rise due to predicted incensement in the population at least by 10% until 2030 (Smol, 2021). It will also be demanding availability of some other basic resources for sustainability of life on earth, such as fresh water and pure air (Pahl-Wostle, 2019). We consume food sources either from plants or from animals. On the basis of sources diets are classified into vegetarian and non-vegetarian. However, there are different kinds of diets on the basis of combinations of plant products and animal products (Tran et al., 2020). Among vegetarians, only consumption of cereals, millets, pulses and vegetables is not considered as a complete diet because of lack of Vitamin B-12, which is found only in animal products. So for vegetarians milk is one of the major components since ancient time is now classified as lacto-vegetarian diet. Milk and milk products are consumed by all age groups of people across the world.

Lacto- vegetarian diet is different from normal vegetarian diet in terms of one animal product called milk, to incorporate vitamin B-12 in human diet and found to decrease the risk of coronary heart diseases indicated by surrogate markers (Johansson, 2012). Lowik et al., 1990 reported that pure vegetarian elderly are at a higher risk for a marginal iron, zinc, and vitamin B-12 status. The aspects of over-population described above have contributed to rise in the demand of dairy products, likewise leading to significant growth of dairy industry in the present era. In the last three decades, world milk production has increased by more than 59% reaching 906 million tonnes in 2020-21 (FAO, 2021). India is the world's largest milk producer, with 22% of global production(FAO,2013). CAGR (Compound Annual Growth Rate) of milk production in India is about 6.2% reaching 209.96 million tonnes in 2020-21(Anonymous, 2021).

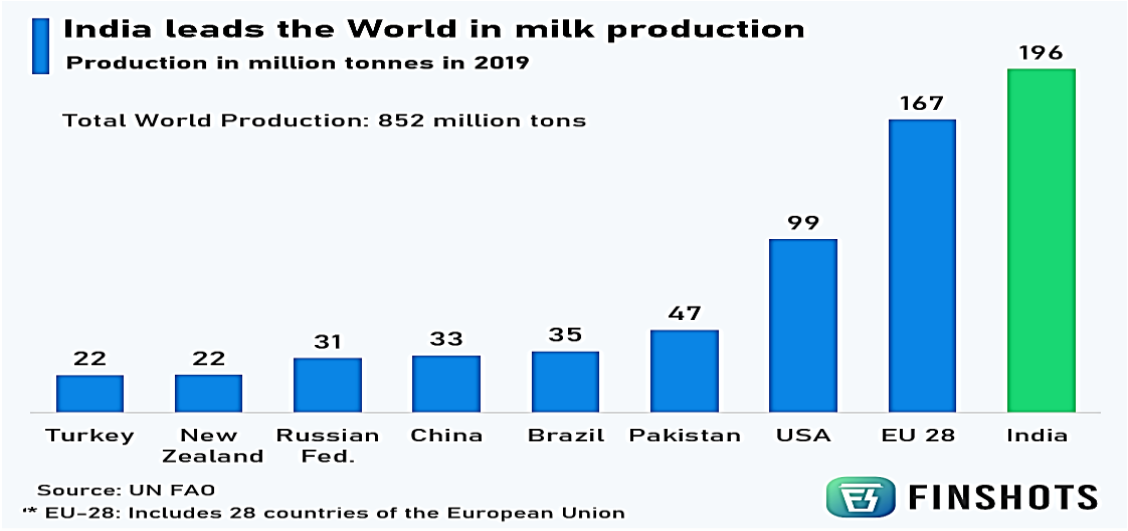

Figure 1: India leads world's milk production (Anonymous, 2020)

So in coming time there is need for not only take precautions on our diet but also for animal's fodder so that India can lead in milk production and can match the demand of world's population.

Table1: Composition of milk (O'Connor et al., 1995).

Main Constituents	Variation (%)	Mean (%)
Water	85.5-89.5	87.5
Total Solids	10.5-14.5	13.0
Fat	2.5-6.0	4.0
Proteins	2.9-5.0	3.4
Lactose	3.6-5.5	4.8
Minerals	0.6-0.9	0.8

In general, milk contains water, total solids, fats, proteins, lactoseand minerals. Composition of milk may vary due to various factors like breed, feed, lactation stage and location of cattle (Needham,1962). Out of these, feed (ration) is the most important factor which translates to quantity and quality of milk produced. Ration prices and availability can have a larger impact on what farmers can use. Good quality fodder crops are one of the most common rationsfor feedingof herd by small marginal dairy farmers. Water for irrigation needs to be applied in order toensure proper growth and development of thefodder crops.

There are many crops belongs to different families are traditionally being used as feed for milching animals. Out of which Sorghum (*Sorghum bicolor* L.) has recently witnessed an increasing importance as forage cropin arid, semiarid, and high-salinity areas as it has a better water-use efficiency and, consequently, can produce more biomass under drought and saline conditions (Wu et al., 2010; Zhang

et al., 2016). Such importance is further accentuated by global warming, increasing water shortages, and growing demand for high quality forage resources (Mohammed, 2010). Because of these features, sorghum silage (SS) is commonly used for livestock feed in Mediterranean countries (Miron et al., 2005). Current production area is 12 million hectares and it is the third major crop after rice and wheat and accounts for about 16 % of the world sorghum production (DayakarRao, 2000). However, over the last 20 years significant decline have been taken place in both area of production and its consumption as feed (Hall et al., 2004).

On the other hand to increase forage production, demand of fertilizers are rapidly growing (Abin et al., 2020)many of which are based on limited fossil resources (Smol, 2021) and a cause of soil, water, food pollution. Therefore, it is urgent need to identify, evaluate and implement sustainable strategies that can not only provide alternative ways to the synthetic fertilizers and their affordability to small farmers but also can reduce waste from environment leading to stop water contamination.

Dairy waste: problem, causes and nutritive value:

Increased urbanization andindustrialization in the developing countries have been the cause of production of a largevolume of wastewater and effluents the disposal of which is becoming a growing concern. Out of all industrial sectors, Dairy industry generates a large quantity of waste waterdue to the excessive consumption of water and high production of effluents per unit of production (Karthikeyen et al., 2015; Ahmad et al.,2019).

It is estimated that dairy industries generate 2.5 to 3 liters of wastewater per liter of milk processed (Sutar et al., 2015).This wastewater (also called as industrial sewage), when typically stored in unlined lagoons, poses groundwater contamination problem. It leads to contamination of drinking water which comes from groundwater supplies (Fassio et al., 2005). Along this waste water mixed with effluents, dairy sector generates food waste inside production unit as well as during supply chain to the consumers. This food waste also called as organic wastecontributes to 21% of all industrial waste(Anonymous, 2012) and among which dairy waste makes 19% of total food waste (Campbell et al., 2022).

Globally about 4–11 million tons of dairy waste is released in the environment every year, which is a serious threat for biodiversity (Ahmad et al.,2019). Most of the dairies dispose this waste in solid

waste disposal site or by incinerating which further generates pollution (Abdeletal., 2018). The waste generated by the dairy industry is expected to witness a CAGR of 5.6% from 2020-2027, owing to the spoilage of products due to unhygienic storage at inappropriate temperatures (Anonym, 2020).

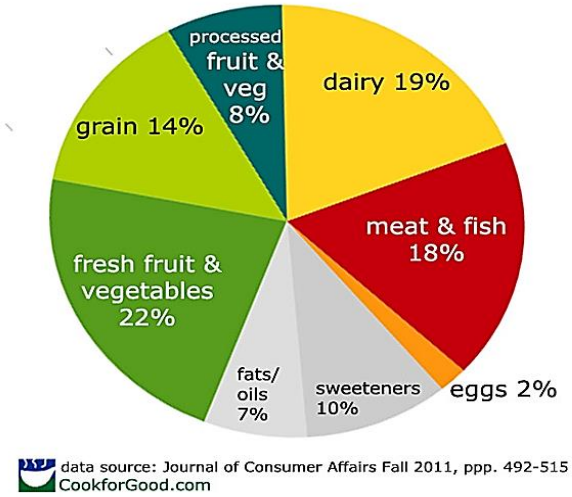

Figure 2: Food makes up larger %age of industrial waste

Figure 3: Food waste by category

Dairy waste includes milk in the spoiled, spilled form, other products and all dairy processing wastes that do not meet applicable quality standards, have become contaminated, unusable for human consumption, animal feed, or any other beneficial use(Indiana Department of Environmental Management, 2002).It may also contain by-products generated during different product preparation. In dairy industry, nature of product determines the quality and quantity of the waste. This organic waste can be generated at the plant during production, processing, handling, storageand packaging or in the steps of supply chain i.e., distribution, retailing or consumer step. Waste generated in plants can be

from cleaning in place (CIP) of equipments, spoilage, manufacturing wastes, leakage, residuals and other wastes (Mehrotraetal., 2016).

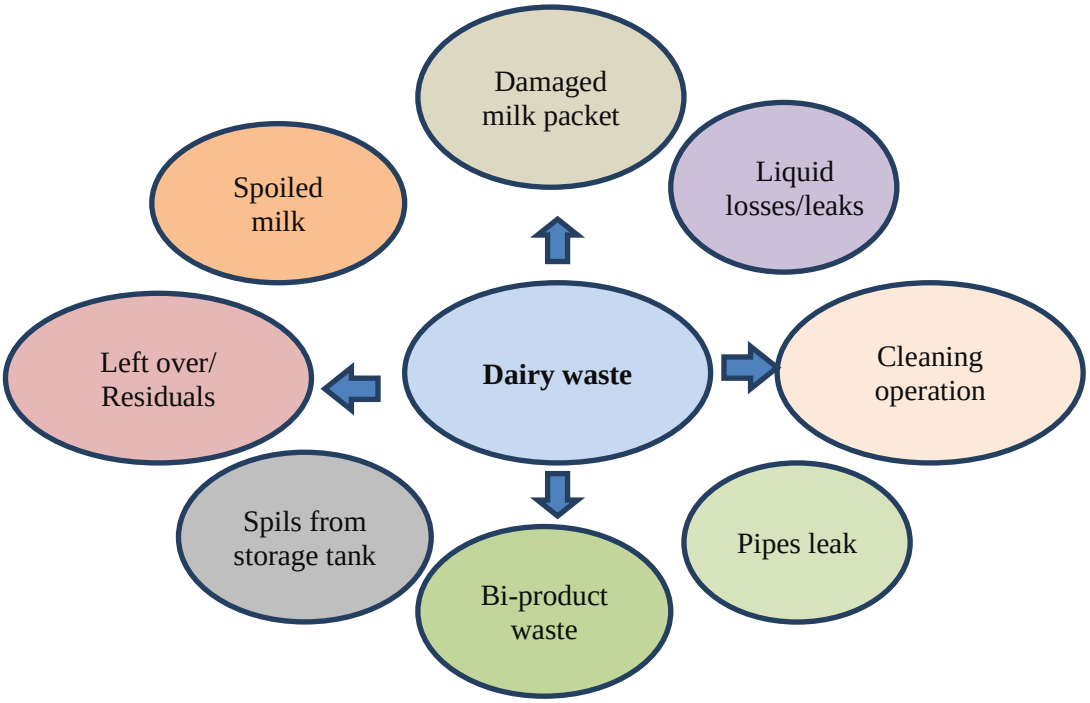

Figure 4: Dairy waste causes

Dairy waste contains soluble solids, high organic matter like protein, lipid, carbohydrate, which comes from washing and sanitation of major processing equipments like pasteurizer, homogenizer, butter churner, heat exchanger, cream separator etc. These wastes have high Biochemical oxygen demand (BOD) and high chemical oxygen demand (COD) thus enhancing pollution when disposed to the environment. Therefore some innovative measures must be taken so as tominimize resource loss and reduce the environmental problem caused by dairy waste (Britz et al.,2004).Large dairies which generate maximum waste are from the milk processing section, cheese section, butter section, condensed and dried milk section, casein production section etc. As organic farming is taking pace all across the globe, the most common organic fertilizer in use i.e. cow dung manure, whichis required in large amount can lead to shortage. Insufficiency of dairy farm manure can be a major concern of future organic farming, Hence it's a high time to find suitable alternative. Therefore, one possible solution can be converting the dairy waste into ecofriendly/organic fertilizer and using it in organic farming.

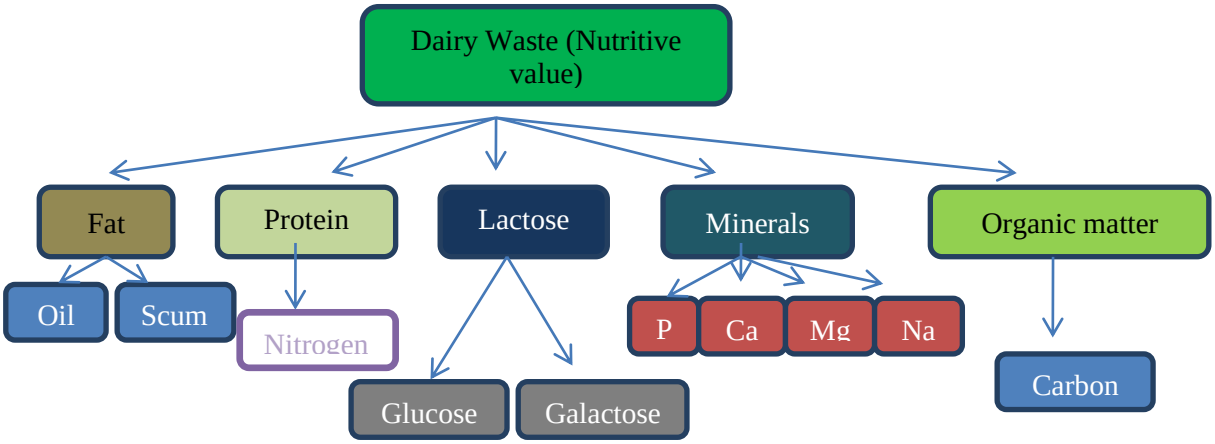

Figure 5: Nutritive value of dairy waste

Dairy waste contains protein, lactose, fat, organic matter and essential elements like nitrogen, phosphorus, calcium, potassium, magnesium which on soil amendment can contribute to enhance soil fertility (Slavovetal., 2017).

Importance of present study:

From introduction it is cleared that dairy waste which is considered as liability can be converted into useful resource. In literature there is no report available which is covered complete study of dairy waste i.e., from development of fertilizer to its estimation for nutrient contents, effect on physical & chemical properties of the local soil, growth, bio-chemical parameters and yield of *Sorghum bicolar* L. So, in thepresent research we will conduct a collective study of all these parameters hence will be made research more effective and sustainable. It will be helpful to establish a complete circular economy system in Dayalbagh, Agra as showed in figure 6 below-

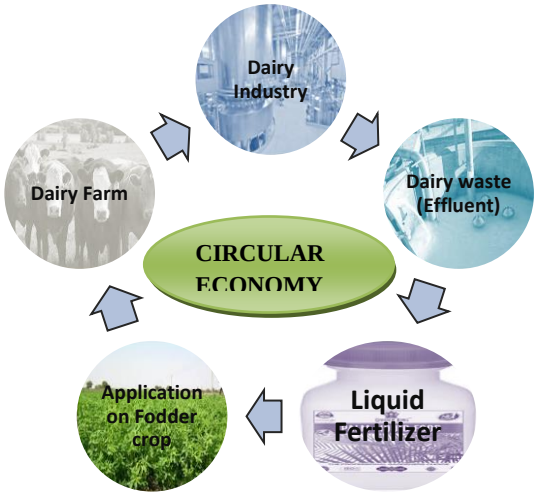

Figure 6: Plan to develop circular economy through present study

Majority of the work done related to conversion of dairy waste into fertilizer has a drawback that they mainly used protein portion while leaving the fat content leading to further generation of waste and their by damaging the ecosystem (Alharbi et al., 2021; Eissa et al., 2018). In present study effort will be given to reduce this waste generation by maximizing utilization of the dairy waste.

REVIEW OF LITERATURE

The application of organic wastes, notably livestock manures, to land has historically beenimportant for maintaining soil fertility in terms of both nutrient status and organic matter levels,as well as helping to reduce soil erosion and improve water holding capacity (Merringtonet al.,2002; Fraisse et al., 1996). Rising fertilizer and food costs in most of countries (FSSA, 2008) have provided the necessity for investigation into more economically viable alternatives to chemical fertilizers.

Dairy waste and/or manure applications as a fertilizer coulddrastically reduce fertilizer costs for farmers, whilst simultaneously alleviate storage andmanagement problems often associated with such wastes on these dairy farms. Waste applicationas a fertilizer to agricultural land is more environmentally friendly and economically beneficialthan the application of chemical fertilizers. By alleviating costs, income to farmers and increasedproduction could drastically benefit not only the farmer him/herself but also the consumer.Within agriculture, input costs such as transport, animal feeds and fertilizer play a large role indetermining the success or failure of a farming enterprise and with the global increase in energyprices (FSSA, 2008), the future for farming in India promises to be a challenging one.

There are numerous studies till date that have been conducted on the feasibility ofrecycling or treating dairy wastewater so that it can be reused in crop production practices(McGarvey et al., 2005; Feng et al., 2005; Lansing et al., 2006; Gottschall et al., 2007). Asolid theoretical background study of the proposed was undertaken through an extensiveinvestigation of both national and international status of the literature.

In the manufacturing of dairy products, there is usually a lot of damage to the environment due to the generation of waste from products and the by-products from dairy foods. Large amounts of these by-products are generally discarded in the ecosystem, especially into the rivers, lakes, seas or soil,

causing considerable environmental pollution, which not only affects the quality of water, air and soil, but even causes climatic variations (De Jesus et al.,2015).

Research has shown that lactose is one of the most polluting by-products due of its high biochemical oxygen demand (BOD) and chemical oxygen demand (COD). When it is discarded in the soil in the form of industrial effluent without any prior treatment, it can modify the soil's physical and chemical composition considerably, reducing to reduced crop yields and the availability of oxygen in water. It has been estimated that 40,000 liters of untreated milk whey produces contamination equivalent to that produced of 250,000 people (De Jesus et al., 2015).

Dairy industry wastes and by-products are potential raw materials to produce a variety of bio-based products meanwhile simultaneously reducing their carbon footprint. The integration of these wastes into the biorefinery will have contribution to the recovery/separation of bio-products, the growth of microorganisms, and the bioeconomy (Sar et al., 2021; Dahiya et al., 2018).

Diacono et al., 2010 suggested that inorganic fertilizers application leads to soil degradation, desertification, erosion, and accelerated greenhouse effects and climate change. These concerns are likely to be increased in the near future.

Reports ofLal 2009, Cardoso et al. 2013 and Singh et al., 2015 concluded that organic amendments can be used to improve soil structure and thus constitute an integral tool for sustainable agriculture which favors microbial biodiversity and activity and promotes long term fertility and productivity.

Diaconoetal.,2010 did comparative study and found that as compared to the other organic fertilizers, dairy waste compost soil additives are helpful to maintain N_2 supply to the plants through continuous mineralization, by increasing organic carbon content when applied at the same available N_2level.

The recent researches showed that, dairy waste can be used for the production ofbioplastic, biosurfactant and biofuel like biodiesel, bioethanol and biomethane(Ahmed et al.,2019; Sharma et al, 2020; Gudiukaite et al.,2021; Usmani et al., 2021; Sar et al., 2021). Some efforts toconvert dairy waste in to the resources are given in Table

Table 2: Current applications of dairy waste

Dairy waste into resources	Product name	References
Biofuel	Biodiesel	Yatish et al., 2022; Balasubramanian et al., 2018; Kavitha et al.,2019; Shivakumar etal.,2011
	Bioethanol	Jianming Liu et al.,2016; Zoppellari et al.,2012; Shen et al., 2019
	Biomethane	Krich et al., 2005; Pandey et al., 2021;Tanzia et al., 2017 ; Eswari et al, 2017
	Biohydrogen	Awasthi et al., 2022; Colombo et al.,2019; Arun et al., 2018
Biopolymers	PHB (Polyhydroxy butyrate)	Sirohi et al.,2020; Mehta et al., 2017
	PHA (Polyhydroxy alkanoates)	Saratale et al.,2021; Tripathi et al., 2021
Plant Feed	Biofertilizers	Alharbi et al., 2021; Eissa et al., 2018; Gogoi et al., 2021

Characterization of dairy waste of typical Indian dairy are compiled below:

Table 3: Characterization of dairy waste (All values except pH are expressed in mg/l)

Properties	Value	References
BOD	1040	Shete et al.,2013
COD	2100	Shete et al.,2013
Ph	6.5	Patil, 2014
TS	2532	Patil, 2014
TDS	1803	Patil, 2014
TSS	1810	Mehrotra et al., 2016 , Mohanrao,1972
Total N	1080	Mehrotra et al., 2016 , Mohanrao,1972
Total P	110	Mehrotra et al., 2016 , Mohanrao,1972
Chloride	112	Mehrotra et al., 2016 , Mohanrao,1972
Sulphates	45	Mehrotra et al., 2016 , Mohanrao,1972
Alkalinity	213	Patil, 2014
Colour	White	Mehrotra et al., 2016 , Mohanrao,1972

According to (Mehrotra et al., 2016) dairy wastes are mainly dilution of milk product resulting due to hygienic requirements of plant and processing of milk and production of different other products. Only a small part of milk produced in India is processed. 18-20% of total milk produced is covered under organized sector. The organized sector processes about 25-28 million tonnes annually. The major constituents contributing to BOD of the dairy waste are lactose, milk fat, protein and lactic acid. The reported values are 0.65, 0.89, 1.03 and 0.63 kg BOD/kg respectively. The BOD: COD for raw Dairy waste is mostly 0.5- 0.7.

Even though treatment and management of waste are well documented, but the main problem is concerned with sludge produced after treatment. There is a gap in the application of various methods for effective treatment of the waste, hence there is a need for technology- oriented research in this area because of a paradigm shift in perspectives towards sustainable management of waste to recover value added products including energy as energy demand is also rising (Adesra et al., 2021)

Shi et al., 2021 stated that current practices in the EU, DPS(Dairy Processing Sludge) is categorized as a biosolidand therefore can be spread on agricultural lands (arable and grassland) as it is rich in both the macro- and micro-nutrients required for healthy plant and animal growth. It also has potential to be used as an additive in compost, animal feed and biofuel or it may be dried and incinerated (Ashekuzzaman et al., 2019).

According to Sar et al., 2022 expired milk, cheese whey and other dairy industry by-products, together with their rich contents, have been considered as inexpensive materials and evaluated as an alternative substrate in microbial production processes (such as bioenergy, enzymes, organic acids, biopolymers, biomass, etc.). The production of some value-added products (e.g., nisin, biomass, lactic acid) can be included in sustainable consumption and production goals. The production of other products such as bioethanol, biogas and biohydrogen can be suitable for affordable clean energy.

Literature suggests that solid dairy sludge could be used at 60% concentration as a substrate for growing rhizobium resulting in low-cost production of biofertilizer (Singh et al., 2015; Gogoi et al., 2021). The treated wastewater enriched in ammonia, phosphate (as polyphosphate granules), and phosphatase enzyme can ensure healthy plant growth (Halderet al., 2020). The toxic effect of the untreated (raw) wastewater addition to the soil ecosystem can thereby be prevented while adding economic value to the dairy waste (Gogoi et al., 2021).

According to Chaudhuri, 2021 insufficient fodder resources and absence of regulations to check the fodder quality is one of the major constraints in sustaining the milk production. The dairy wastewater with enhanced phosphate and nitrate along with a high carbon: nitrogen ratio could be used directly for sustaining bacterial growth. This property causes nuisance when the wastewater is left unattended.

OBJECTIVES

Present study will be accomplished with the following objectives:

1. Development of fertilizers from dairy waste
2. Estimation of nutrient contents in the developed fertilizers
3. Evaluation of the effect of developed fertilizer on soil properties, growth, biochemical and yield of *Sorghum bicolor* L.

METHODS AND METHODOLOGY:-

1:DEVELOPMENT OF FERTILIZERS FROM DAIRY WASTE:-

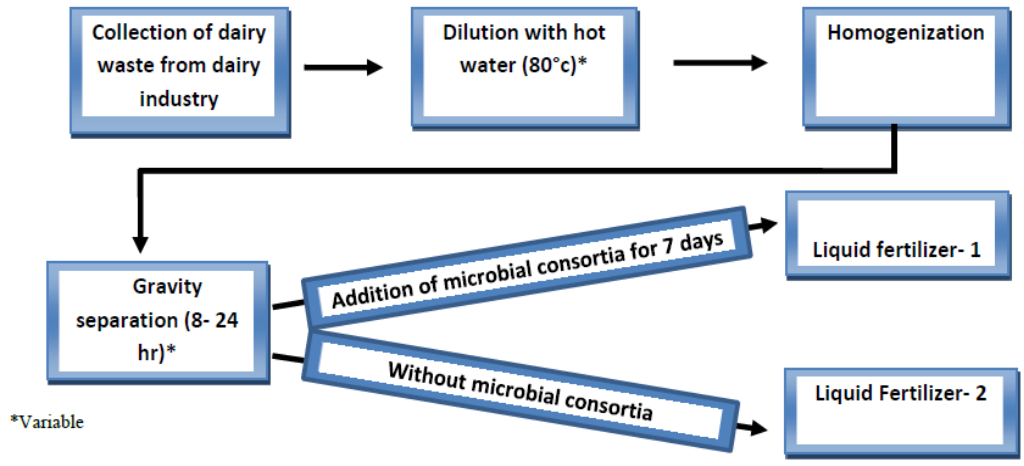

Figure 7: Development of fertilizer from dairy waste (Eissa et al., 2018)

Dairy waste will be collected from any dairy industry of local area and will be processed as per the plan represented in above figure. Microbial cultures will be procured from any recognized facility center. In present study we will be using a mixed consortia of two microbes i.e., *Pseudomonas aeruginosa* and *Enterobacteraerogenes* as both were found to have maximum lipolytic activity in the previous studies (Tzirita et al., 2019; Hidayat et al, 2014).

2:ESTIMATION OF NUTRIENT CONTENTS IN THE DEVELOPED FERTILIZERS

The fertilizers developed from dairy waste will be estimated for its nutrient content and for any pesticide residue as follows-

Organic carbon: By method of Nelson &Sommers, 1996.

Macro and Micro Nutrients:

Nitrogen (N)- Singh and Pradhan, 1981

Phosphorus (P)-Bhargava&Raghupati, 1993

Potassium (K)-Bhargava&Raghupati, 1993.

Calcium (Ca)- Cheng and Bray, 1951.

Iron (Fe)- Loveland Digby, 1984.

Copper (Cu)- Lindsay and Norvell, 1978.

Magnesium (Mg)- Cheng and Bray, 1951.

Zinc (Zn)- Shaw and Dean, 1952.

Additionally pH will also be estimated by using pH meter (Jackson, 1973).

Pesticide residue: By following AOAC Official Method 2007.01 (Lehotay, 2007) by using GCMS/ LCMS technique.

3:EVALUATION OF THE EFFECT OF DEVELOPED FERTILIZER ON SOIL PROPERTIES, GROWTH, BIOCHEMICAL AND YIELD OF *SORGHUM BICOLOR* L.

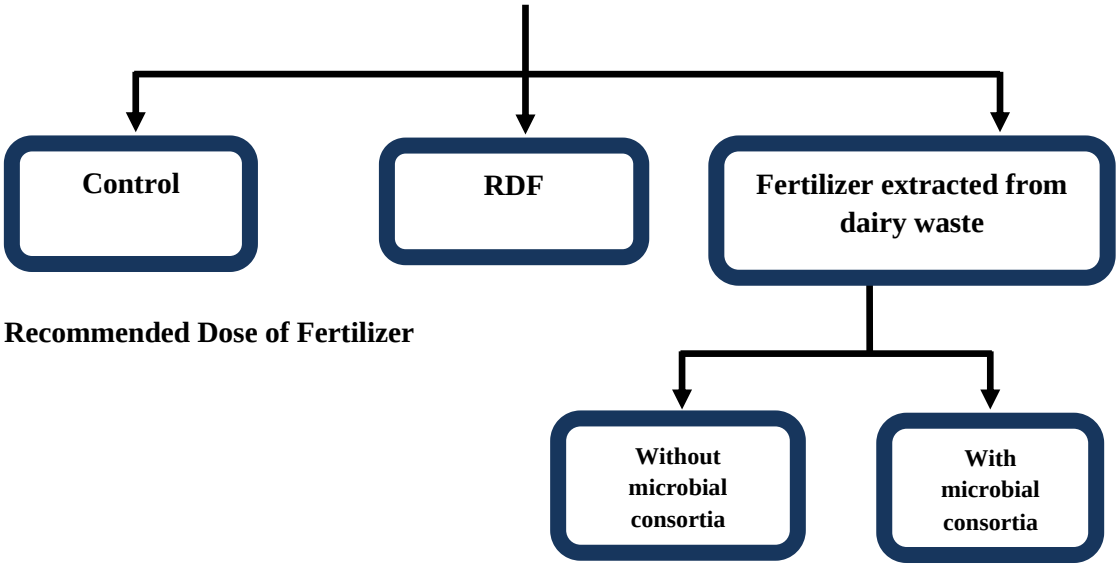

Figure 8: Evaluation of fertilizer from dairy waste

After estimation of nutrient contents in the developed fertilizers, the best one will be taken to evaluate its effect on soil properties, growth, biochemical and yield parameters of *Sorghum bicolor* L.

i. Evaluation onsoil properties:

Soil treated with or without treatments will be analyzed for physical and chemical parameters by following standard protocols.

- Texture, Moisture, water holding capacity, pH, - (Pandeya et al., 1968)
- EC, Organic Carbon, Nitrogen estimation – (Jackson,1973)

ii. Evaluation ongrowth, biochemical and yield parameters :

Effect of developed fertilizer on the growth, yield parameters will be done by manually recording of data and with the help of related instruments as follows-

- Shoot length, number of leaves, leaf area (by LI-COR leaf area meter), biomass (fresh & dry) will be analyzed as yield parameter at the time of crop harvesting.
- Bio-chemical parameters will be analyzed by following standard protocols as follows-

Total chlorophyll (by Mac Kinney (1941), protein(by Lowry's, 1951),sugar (by DuBoiset al., 1956).

EXPECTED OUTCOME

A new fertilizer may be developed which may enhance the soil fertility, growth and yield of *Sorghum bicolar*L.thus converting waste to wealth and sustainability.

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